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Analysis of Main Accident Contributor according to Process Safety Management Elements Failure

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Process safety management (PSM) covers the aspect of process hazard identification, understanding the level of risk and hazard reduction to prevent process-related failures. The need for understanding on how the process safety elements fail is essential in improving the quality of the accidents prevention effort. In this paper, the contributions of PSM element to chemical process accident are studied using major process failures in the chemical process industry (CPI). Around 770 major accident cases were collected and analysed from several accident data base such as Chemical Safety and Hazard Investigation Board (CSB-US), European Major Accident Reporting System (EMARS), Failure Knowledge Database (FKD-Japan) and Accident Reporting Information Analysis (ARIA). The PSM element failures were ranked in accordance to their frequency and importance in accident prevention. Based on the result, majority of the element failure is classified as design and technical reasons (53 % of total process failures) and the rest is related to management related causes (47 %). The most common accident contributors were identified to be the process hazards analysis (19 % of total process failures), operating procedures (17 %), employee participation (12 %), training (11 %), management of change (9 %), mechanical integrity (9 %), and permit to work (9 %). In depth, analysis on individual PSM elements were made for better understanding on their readiness and its implementation issues in the CPI. Appropriate suggestion for continuous improvement of PSM implementation will also be suggested.

1. Introduction

Modernisation in industrial sector with more sophisticated machinery and equipment has create a new hazard if it is not handle with proper approach and management of failure. The trend of accident rate shows a fluctuation trend while manufacturing sector is still recording the highest trend each year (DOSH, 2016). In Malaysia, Process Safety Management (PSM) is not exactly a new agenda, but the implementation of PSM is only voluntary and there is still no evidence of execution enforcement towards implementation. PSM covers the aspect of process hazard identification, understanding the level of risk and hazard reduction to prevent process-related failures (Amyotte, 2007). While some of the company from another section of the world are trying to implement PSM based on their corporate requirement, meanwhile in Malaysia, the awareness of PSM is still very low among our local industries since we are still focusing and grooming the industrial player about the occupational safety and health (OSH) approach instead of PSM. **When the industries** are more focus on OSH practices as compared to PSM, there will be room for failure such as failure of asset integrity and reliability, weak process safety culture and other process safety failure. We can claim in this scenario that Malaysia are still quite behind in implementing PSM and the knowledge are still very low as compare to United Kingdom, United States and European section which is the result of the lack of research about PSM in Malaysia that make it hard to be implemented in the industries. Analysis of the individual PSM elements in terms of its contribution to the accidents in chemical process industry (CPI) will make a better understanding and preparation of the PSM implementation in Malaysia.

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2. Process Safety Management

2.1 Initial of PSM Element

Initial implementation of PSM in 1990 by United States Department of Labour strengthening current OSHA standard during that time to recover the issues about the chemical release such as those happened in major disasters including the 1984 Bhopal, India, an incident resulting in more than 2,000 deaths; the October 1989 Phillips Petroleum Company, Pasadena, Texas, an incident resulting in 23 deaths and 132 injuries; the July 1990 BASF, Cincinnati, Ohio, an incident resulting in 2 deaths, and the May 1991 IMC Fertilizer, Sterlington, Louisiana, an incident resulting in 8 deaths and 128 injuries (US Department of Labor, 2000).
Based on the incident from past and lesson learn, the standard has been enacted into law in year 1990 where 14 minimum elements of PSM must be followed by employer. Some companies have chosen to scale down or compromise the scope of their process safety activities and adopting 20-element risk based (RBPS) framework for process safety. This approach can be implemented and meet the needs of all industry sectors including those with or without high risks (CCPS, 2012).

2.2 Implementation of PSM in Malaysia industries.

With recent amendment of Factory and Machinery Act 1967 (amendment 2014) and Occupational Safety and Health Act 1994, there is no specific sentences showing to implementation of PSM in the act or regulation. Until now, there are still no clear implementation and enforcement for industries in Malaysia to strictly follow PSM approach which consist of 14 or 20 elements. In Malaysia, implementation of PSM are based on voluntarily approach and normally due to the requirement of the parent company that the establishment of their company are following the practices which they had in their region of origin, for standardisation purpose. If compare to another country such as Singapore, Japan, Australia, United Kingdom and European country, Malaysia are still behind in understanding and implementing PSM. Figure 1 below showing comparison of PSM implementation based on PSM element in selected countries compare to Malaysia (Chin et al., 2015).

Table 1: Comparison of PSM Element among selected countries (Chin et al., 2015)

Element	US	EUROPE	JAPAN	S'PORE	MALAYSIA
1 Process Safety Information	Y	Y	Y	Y	N
2 Process Hazard Analysis	Y	Y	Y	Y	N
3 Operating Procedures	Y	Y	Y	Y	Y
4 Employee Participation	Y	Y	Y	Y	N
5 Training	Y	Y	Y	Y	Y
6 Contractors	Y	Y	Y	Y	Y
7 Pre-start up Safety Review	Y	Y	Y	Y	Y
8 Mechanical Integrity	Y	Y	Y	Y	Y
9 Hot Work Permit	Y	Y	Y	Y	Y
10 Management of Change	Y	Y	Y	Y	Y
11 Incident Investigation	Y	Y	Y	Y	Y
12 Emergency Planning &Response	Y	Y	Y	Y	Y
13 Compliance Audits	Y	Y	Y	Y	N
14 Trade Secrets	Y	Y	Y	Y	N
15 Process Safety Culture	Y	N	N	N	N
16 Compliance with Standard	Y	N	N	N	N
17 Process Safety Competency	Y	N	N	N	N
18 Stakeholder Outreach	Y	N	N	N	N
19 Measurement & Matrices	Y	N	N	N	N
20 Management Review Continuous Improvement	Y	N	N	N	N
Total No of Elements practiced	20	14	14	14	10

Some of the industries such as oil and gas industries are actually implementing PSM but unfortunately the information about how deep the implementation is not shared to public. This implementation especially for the upstream process are crucial since the risk of failure is high and the execution of PSM has been much help. Anyhow, the requirement for the implementation is a part of insurance and global policy for oil and gas to ensure safe operation of the business. It can be conluded thatthere are still a lot of gap for Chemical process industries

(CPI) at downstream and normal industries to follow. We also can say the study or research about the compatibility of PSM into CPI for Malaysian industries is still lacking.

3. Research Approach

A comprehensive reading has been done using online database such as US Chemical Safety and Hazard Investigation Board (CSB-US), European Major Accident Reporting System (EMARS), Failure Knowledge Database (FKD-Japan) and Accident Reporting Information Analysis (ARIA). 770 cases have been sort and segregate based on PSM element. The accident reports were analysed to identify the accident contributors and their root causes. The accident contributor is identified based on the 14 PSM elements failure which is described in Table 2.

Table 2: Description of PSM Elements Failure

Failure	Description
Employee participation	Failure of informing employee about relevant safety and health issues
Process safety information	Failure on providing written process safety information pertaining hazards of chemicals used, process and equipment involved
Process hazard analysis	Failure of ensuring availability and continuous update of PHA that identify, evaluate and control the hazards
Operating procedures	Failure on providing written procedure that technically accurate, understandable to employees and periodically revised
Training	Failure of providing appropriate training to the affected employees
Contractors	Failure to inform to the contract employers of the known hazards
Pre-start up safety reviews	Failure to review & update on P&IDs, operating procedure, incident investigation & PHA recommendations or compliance audits before beginning the start-up
Mechanical integrity	Failure to provide mechanical integrity programs such maintenance procedures, criteria for acceptable test results, or documentation of test and inspection results
Hot work permit	Failure to document and execute hot work procedure before conducting hot work
Management of change	Failure to document, maintain and provide appropriate procedure to manage a change such as copies of process changes must be kept in an accessible location
Incident investigation	Failure to record and document the underlying causes of incidents and implementing steps to prevent similar events from occurring.
Emergency planning and response	Failure to provide efficient emergency preparedness training and programs to the affected employees
Compliance audits	Failure to provide sufficient facts and information, including statistical information, to verify compliance with standards.
Trade secrets	Failure to make available of all information necessary to comply with PSM, without regard to the possible trade secret status of such information

4. Result and Discussion

According to 14 elements of PSM, we identify 53 % of failure are contributed by design and technical reason and another 47 % are contributed by the management related causes. From the ranking made, process hazard analysis (PHA) is the major contributor with ranking 1st (19 %) in the PSM element while operating procedures rank 2nd (17 %). Employee participant ranking 3rd with 12 %, training (11 %), management of change (9 %), mechanical integrity (9 %) and permit to work (9 %).

4.1 Process Hazard Analysis (PHA)

PHA is a thorough, orderly, and systematic approach for identifying, evaluating, and controlling the hazards of processes involving highly hazardous chemicals. Lack of process hazard analysis (PHA) implementation in chemical process industry (CPI) contributes to the highest ranking in PSM element failure. This shows that we are way behind in implementing PSM in our CPI. Malaysian industry do not understand the potential hazard in their process yet since the attitude of managing hazard is still at the lower level of understanding. Other than the self-awareness regarding PHA, there are no acts, regulations or orders that has been enforced by the government to be followed by the CPI. The generalisation of act we had currently is sitting at the lowest requirement for various types of industries. Most of people would say thatsafety is unbeneficial to the company capital investment but according to Trevor Kletz, a process safety expert: ”if you think safety is expensive, try to have an accident. Accident cost a lot of money in terms of damage to the plant, claim for injuries, and the loss of company reputation” (CCPS, 2012).

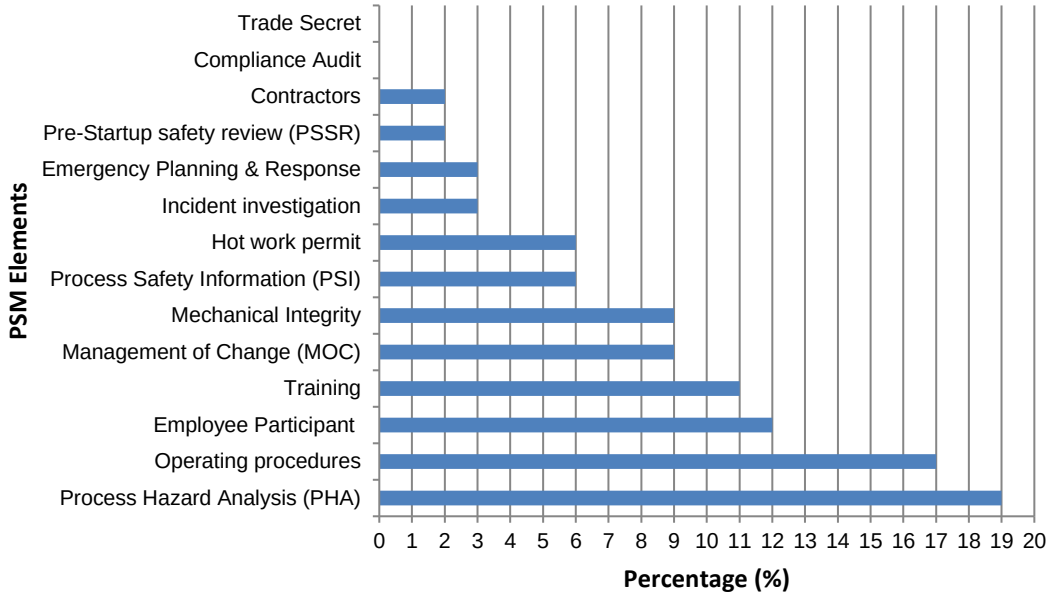

Figure 1: The contribution of PSM elements to accidents in the CPI

4.2 Operating Procedures (OP)

Operating procedures is a set of guideline for the operator to run the process. Running the process is inclusive of:

1. Initial start-up
2. Normal operations
3. Temporary operations
4. Emergency shutdown
5. Emergency operations
6. Normal shutdown
7. Start-up following turnaround
8. Consequences of deviation
9. Steps required to correct or avoid deviation

Missing of standard operating procedures (SOP) creates a room for error since there is no specific guideline to handle the process. Each of the operators will have their own way and style to perform the operation hence resulting in higher tendency of something to go wrong. This is due to unstandardised procedures to handle the operation. Some people are also prone to take a shortcut without thinking of the consequence of their action. This action willcontribute to failure and creating hazard to operation and peoples' life and as well as the environment.

4.3 Employee Participant

In Malaysia, the culture to promote employees' participation in PSM are still low. The culture that are commonly adapted is mostly requesting the employee to focus on their designated work and job scope only. We are still not yet being open to embedded employees' input to improve the PSM. Suggestion for improvement from the operative level are supposed to be taken into consideration since they are the one who had been directly involved in the operation either in the manual or automated process.

4.4 Training

In OHSAS 18001 or PSM, both are emphasising on the training to ensure understanding of process and the hazard embedded inside the process. This will make the operator realise and know about the process hazard and therefore the identification on the system upset can be determined as soon as possible. On the other hand, a good training will actually improve the system function and the operation by the operator. They will ensure the system work in what is suppose since they know the risk and magnitude of damage when the system is down.

4.5 Management of Change (MOC)

To eliminate occurrence of failure due to process changes or system changes, a review on impact of changes to operators' safety and health must be conducted. These changes could contribute to failure when operator is not aware of the changes and still using previous method to operate the process. The reviews on standard operating procedure are thus crucial to close the gap and sufficient training must be conducted to ensure a paramount level of understanding among the operator. An establishment of a set of rules has to be considered before any changes can take place, such as setting a format that can ensure top management are aware of the changes and the changes are communicated to operative level to ensure that the compliance are followed without prejudice.

4.6 Mechanical Integrity

There is a lot of issues involving mechanical integrity such as design failure, fabrication failure, maintenance failure, equipment deficiency management and others. For an example, during 1970s, there were many incidents that occurred due to the wrong type of steel supplied. For instant, the stainless steel incident in the 304 L/ 316 L where the acidic by-product formed and attacked the 304 L steel due to steel composition which allow it to be degraded. This is an example of the design failure where the material selection for modification can go wrong (Kletz, 2003).

4.7 Process Safety Information

Process safety information consists of 3 main agenda:
a. Information of highly hazardous chemical in the process
b. Information of the technology of the process
c. Information of the equipment in the process.
According to (a), all the necessary information such as toxicity, permissible, reactivity, corrosivity and thermal and chemical stability data. While the information about technology of the process will explain about the permissible exposure limit (PEL), maximum intended inventory, safety upper and lower limit and evaluation of consequence of deviation including those affecting employees in term of safety and health. Information on the equipment in the process should have the P&ID, simplified block diagram which will easily make the operative level to understand the behaviour and character of the equipment, relief system design and design basis, design code and others. The information will help the system handler to understand, get to know the character and to analyse the requirement as to minimise the hazard when handling the process plant.

4.8 Hot work permit

Hot work permit system is one of the methods of controlling fire hazard. This method enables the management to control the source of fire and taking some necessary counter measure such as preparing fire extinguisher, secondary containment, fire watch and others. Unfortunately, not many people agree on the execution and some people are prone to say this is some kind of burden to them and the execution will consume lot of time. Ignoring the preliminary containment can cause a catastrophic event.

5. Conclusion

If we are comparing between Malaysia and other developed country which practicing PSM in CPI, we are way behind in terms of implementation. Segregation made upon cases reference to PSM element has shown that we are lacking in terms of understanding and implementation of process safety management in Malaysia. Besides not having many experts in PSM which includes the study on the element of PSM and management of Risk Base Process Safety (RBPS), we are still not up to the global standard where most of European, United States, United Kingdom, Japan and even Singapore, who has already established a good approach in managing PSM in CPI. Review on current Factory and Machinery Act should embedded PSM approach to strengthened the practice base on RBPS (20 element) to reduce the potential of having risk in CPI should take place in near future and should tally with the industrial revolution we had recently and in future. Setting up a milestone journey for the improvement are needed to ensure a set of act will be an encouragement for the local industry to implement the process safety approach and targeting on next 10 y perhaps, that the execution of PSM will be on voluntary approach and no longer based on enforcement which the industries are determine to emphasise PSM in their daily operation. Partnership between governments such as Malaysia – Singapore – European Union – United Kingdom and others should be established and PSM should be one of the important elements to be discussed to improve the knowledge, awareness and implementation. Integrated database can also be established to have a good partnership and support.

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